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USAARU REPORT NO. 68-6

SOUND ATTENUATION CHARACTERISTICS OF THE NAVY BPH-2 HELMET

By

Robert T. Camp, Jr., DAC

MARCH 1968

U. S. ARMY AEROMEDICAL RESEARCH UNIT
Fort Rucker, Alabama

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SOUND ATTENUATION CHARACTERISTICS

OF

THE NAVY BPH-2 HELMET

INTRODUCTION

Army Technical Bulletin T. B. Med 251, 25 January 1965, requires the initiation of a hearing conservation program when the ambient environmental noise is greater than 92 db in the 150 to 300 Hz octave-band and 85 db in all higher octave-bands through 9600 Hz. Spectrum analyses of all types of Army aircraft have shown that the Army aviation personnel work in sound pressure levels much higher than the above criterion. USAARU Report 67-6 on the sound attenuation characteristics of the Army APH-5 helmet has shown that the standard APH-5 helmet does not have adequate attenuation to protect against these high sound pressure level noises. As part of an effort to investigate the possibilities of obtaining higher attenuation in a crash protective helmet, USAARU Report 67-8 has shown that the Navy SPH-3 (Modified) (LS) helmet is an efficient attenuator of sound. This Laboratory has also investigated the attenuation characteristics of the Navy BPH-2 helmet. This report is concerned with the real-ear attenuation characteristics of the BPH-2 and compares its relative attenuating efficiency with the data on the APH-5 and SPH-3 (Modified) (LS) helmets. See Figures 1 and 2.

PROCEDURE AND EQUIPMENT

The evaluation of the sound attenuating characteristics of the Navy BPH-2 helmet was accomplished with procedures, equipment and physical requirements specified in <u>The Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold, ASA Z24.22-1957</u>.

One additional low frequency test tone (75 Hz) was added to nine standard frequencies 125, 250, 500, 1000, 2000, 3000, 4000, 6000, and

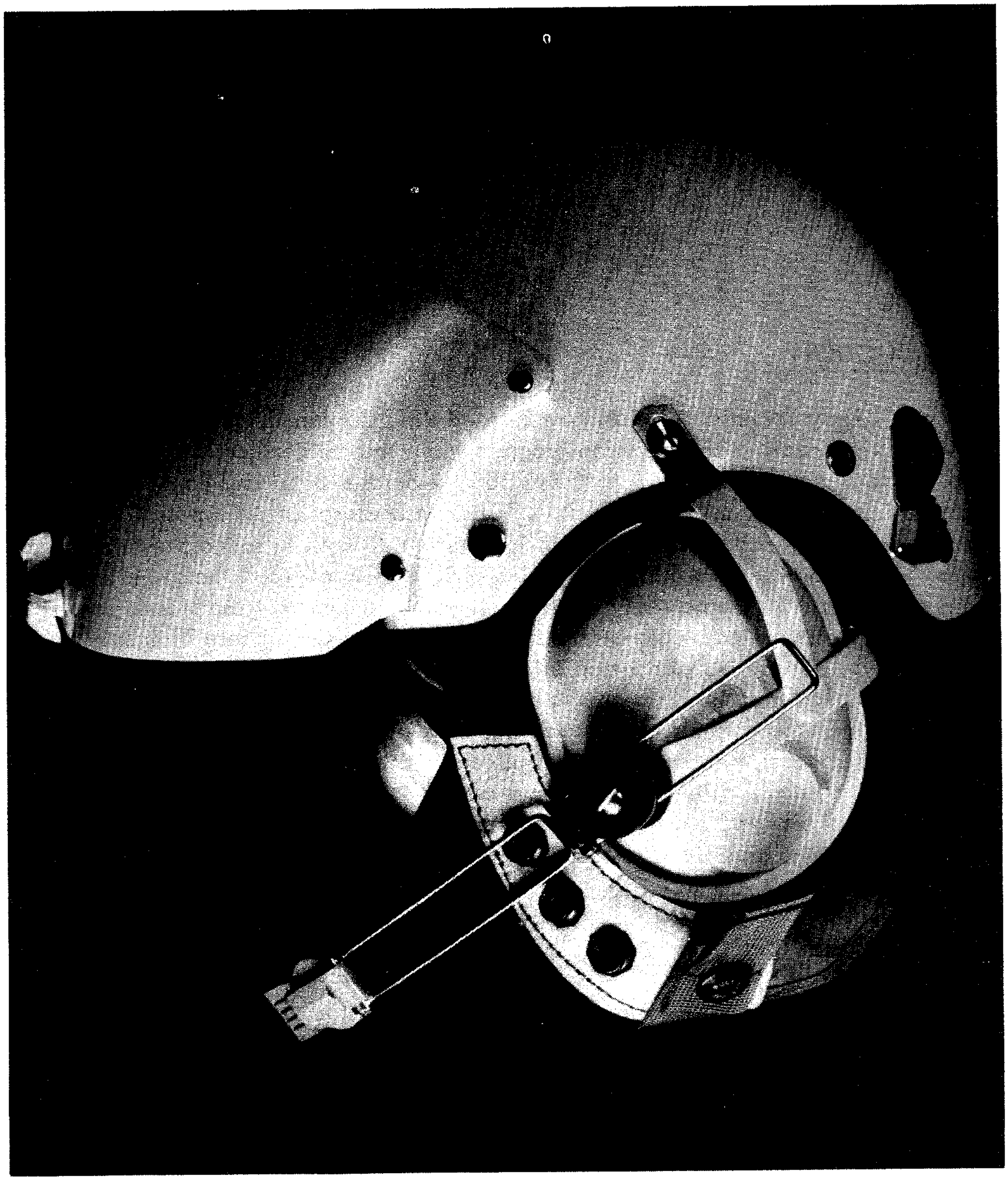


Figure 1. Side View of a Navy BPH-2 Helmet

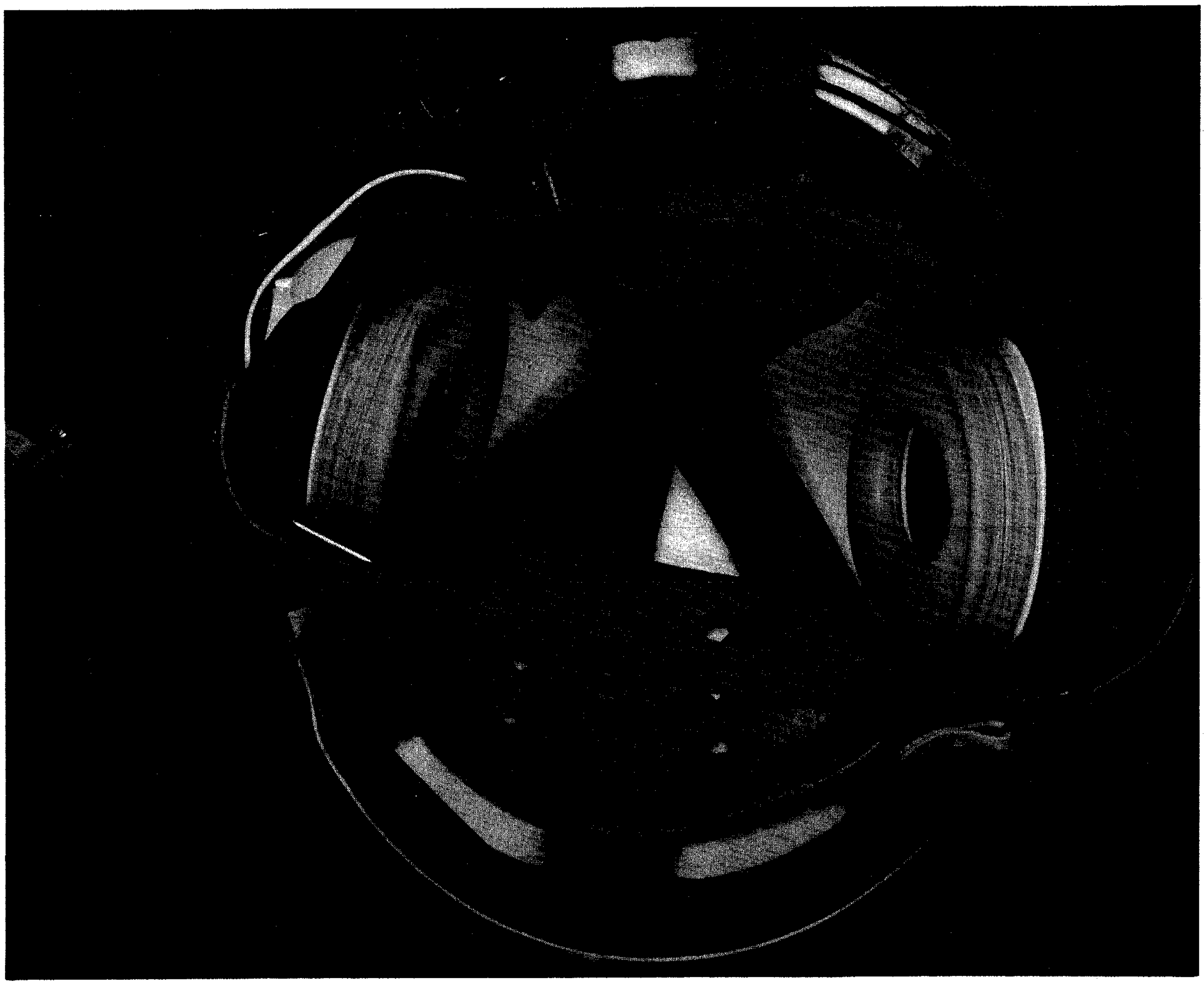


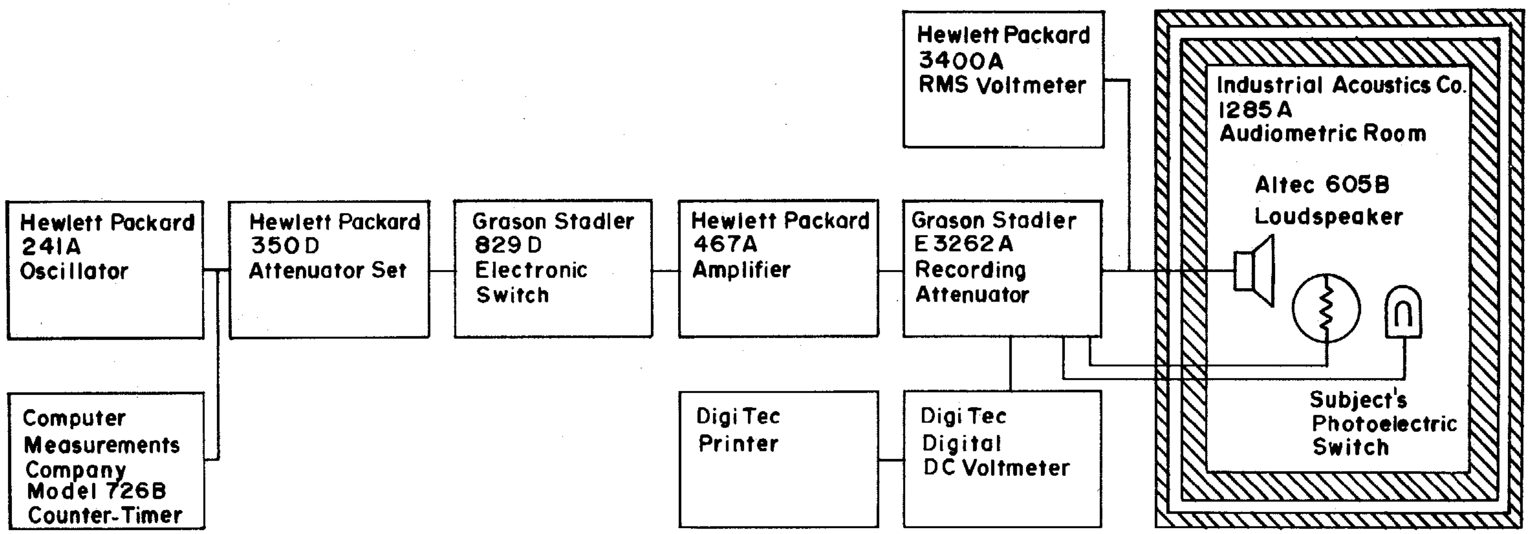
Figure 2. Bottom View of a Navy BPH-2 Helmet

8000 Hz. The tones were generated by a Hewlett Packard 241A oscillator. See block diagram of instruments in Figure 3. The output of the oscillator was connected to a step attenuator set, a Hewlett Packard 350D with a range of 110 db in one db steps. This attenuator provided the experimenter with a calibrated control of test tone levels for checking subject's reliability; also, the control of over-all sound pressure levels of test tones was necessary for subjects with extremely low thresholds and for boosting levels when testing attenuating devices of high efficiency.

The output of the 350D attenuator was fed into a Grason Stadler 829D electronic switch. The electronic switch interrupted the test tones with a 50% duty cycle and with off and on durations of 500 msec. The rise and decay time of the switch was 50 msec. The signal from the electronic switch was amplified with a Hewlett Packard 467A power amplifier.

A Grason Stadler E3262A recording attenuator was inserted between the power amplifier and an Altec 605B loudspeaker. The recording attenuator was provided with control switches that may be operated by the subject and the experimenter. The subject's switch was a photoelectric clickless type. The experimenter's switch had facilities for changing directions, stopping the attenuator and overriding the subject's control. Having the recording attenuator on the output of the power amplifier provided attenuation of the test signal and amplifier noise. The voltage to the loudspeaker was measured with a Hewlett Packard 3400A RMS voltmeter. The circuit was calibrated with this voltmeter at the beginning of each test.

In addition to the recorded information on the recording attenuator paper, there was digital print-out of the attenuation values. A potentiometer was coupled mechanically to the recording attenuator which controlled a DC voltage as a function of attenuator setting. The voltage across the potentiometer was adjusted to indicate 1.000 volt on a Digi Tec digital DC voltmeter when the recording attenuator was set at 100 db attenuation. By arbitrarily moving the decimal point, the voltage indication may be taken as a representation of the attenuation value of 100.0 db. The linear relationship between the change of attenuation of the recording attenuator and the accompanying voltage change across the potentiometer yields digital voltage readings that are numerically identical to attenuation values registered on the recording attenuator. This information was printed by a Digi Tec printer which was connected to the digital voltmeter. This arbitrary system of representing attenuation values with voltage readings had a resolution equivalent to one-tenth decibel.



BLOCK DIAGRAM OF INSTRUMENTATION FOR REAL-EAR ATTENUATION TEST

Figure 3

The recording attenuator circuitry was provided with a one shot monostable multivibrator circuit that sent a print command each time the subject changed recording attenuator direction. With a Bekesy type response for constant test tones, there was an oscillation of attenuator values around the subject's threshold. This oscillation is due to the activation and release of the attenuator control switch when the listener perceives and ceases to perceive the acoustic stimuli, respectively. The print-out facility provided digital print-out of minimum and maximum values of the oscillations around the subject's threshold. The printer also provided a sum total of the response values at the command of the experimenter.

A quiet environment was provided by the Industrial Acoustics Company 1285-A double wall audiometric room. The intensity gradients were measured for certain test tones as required by the ASA Z24.22-1957. Tables I through III contain sound pressure levels measured in one inch increments along three axes from the subject's head. These were the normal maximal sound pressure values of each test tone after calibration. The 1285-A has extremely high attenuation characteristics throughout the audio spectrum. Table IV is a tabulation of a one-third octave-band statistical analysis of the room noise. The system noise of the instrumentation used to measure the room noise is also shown. The noise measurement instrumentation was a calibrated one-inch Brüel & Kjaer microphone, a Brüel & Kjaer Audio Frequency Spectrometer Type 2112, a Brüel & Kjaer Level Recorder Type 2305, and a Brüel & Kjaer Statistical Distribution Analyzer Type 4420. The system noise measurements were done with the microphone cartridge replaced by a 50 pico farad capacitor.

RESULTS AND DISCUSSION

Table V and Figure 4 show the results of the real-ear sound attenuation test on the BPH-2 helmet. A comparison of these attenuation characteristics with the characteristics of the Navy SPH-3 (Modified) (LS) helmet shows that the two helmets yield similar results at 250 Hz, 4000 Hz, 6000 Hz, and 8000 Hz. The BPH-2 yielded 1.71 db, 0.96 db and 2.52 db greater attenuation at 250 Hz, 4000 Hz, and 8000 Hz, respectively. At 6000 Hz the mean attenuation value was 1.30 db less than the value obtained with the SPH-3 (Modified). These small differences are not statistically significant at the one per cent level of confidence. The differences of 4.74 db, 2.49 db, 7.23 db and 6.48 db at test frequencies 75 Hz, 125 Hz, 2000 Hz, and 3000 Hz were statistically significant.

Table I

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches Below the Normal Head Position						Normal Head Position	Distance in Inches Above the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	70.5	70.6	70.8	71.2	71.4	71.6	71.8	71.7	71.8	72.1	72.3	72.3	72.5
125	77.2	77.6	77.8	77.8	78.0	78.2	78.5	78.5	78.7	79.0	79.2	79.4	79.6
250	84.3	84.3	84.1	83.6	83.4	82.9	82.8	82.6	82.4	82.0	81.8	81.6	81.5
500	89.4	89.3	89.1	89.0	88.9	88.6	88.6	88.5	88.5	88.6	88.6	88.7	88.8
1000	84.9	84.8	84.6	84.4	85.2	85.6	86.2	86.2	86.0	85.7	85.4	84.7	84.3
2000	85.6	85.8	85.5	84.6	84.0	84.2	84.8	84.9	84.8	84.4	84.0	84.4	85.0
3000	83.8	83.4	85.6	86.2	85.4	83.4	85.0	86.6	87.3	85.8	84.8	85.0	85.2
4000	84.1	85.0	84.8	85.4	87.8	87.0	85.2	85.4	84.6	84.4	84.8	84.0	82.1
6000	72.6	71.7	72.8	77.8	80.5	84.2	82.0	82.0	80.6	76.4	78.1	77.2	77.3
8000	79.2	78.0	77.9	81.1	81.8	83.4	83.6	84.2	85.1	82.4	84.4	81.1	83.0

Table II

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches in Front of the Normal Head Position						Normal Head Position	Distance in Inches Behind the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	76.7	76.1	75.4	74.6	73.9	73.3	72.2	71.4	70.7	70.0	69.2	68.6	68.3
125	81.1	80.6	80.4	80.0	79.6	79.2	78.6	78.4	78.1	77.8	77.2	77.4	76.6
250	80.8	81.5	82.8	81.9	82.6	82.8	83.0	83.2	83.5	83.6	83.7	83.7	83.6
500	87.2	87.8	88.0	88.4	88.5	88.5	88.2	88.1	87.9	87.6	87.3	86.7	86.6
1000	86.0	84.6	83.4	83.7	84.7	86.0	86.6	86.5	85.8	84.6	83.3	82.4	82.5
2000	83.4	84.2	86.7	85.7	81.8	82.9	85.3	84.0	80.0	82.0	84.2	83.4	81.3
3000	82.6	83.8	83.4	83.6	85.3	82.0	82.6	80.2	78.8	83.3	79.5	84.4	85.8
4000	84.9	85.7	85.5	85.3	85.8	84.3	84.5	82.6	85.0	84.1	83.0	83.2	81.2
6000	78.0	81.4	80.6	77.8	79.0	81.2	82.8	72.6	77.8	80.8	82.0	75.0	77.8
8000	79.6	78.6	82.6	82.0	82.0	82.7	82.4	80.1	80.6	80.2	82.1	79.8	80.6

Table III

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches Left of the Normal Head Position						Normal Head Position	Distance in Inches Right of the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	71.6	71.6	71.7	71.7	72.1	72.0	72.3	72.3	72.3	72.4	72.4	72.5	72.3
125	78.1	78.2	78.3	78.4	78.6	78.5	78.6	78.8	78.9	78.9	79.0	79.0	79.0
250	82.4	82.5	82.6	82.7	82.8	82.8	82.9	83.0	83.1	83.1	83.1	83.1	83.2
500	88.2	88.5	88.7	88.9	89.0	88.9	88.9	88.6	88.4	87.9	87.5	87.0	86.4
1000	85.2	85.7	86.1	86.4	86.6	86.3	86.0	85.4	84.7	84.1	83.6	83.4	82.6
2000	83.0	83.2	83.7	84.5	84.7	84.9	85.2	85.1	85.1	84.7	83.3	82.6	84.4
3000	84.7	82.9	82.5	80.9	80.8	82.3	84.6	86.2	85.2	82.6	81.2	82.4	85.0
4000	82.4	82.0	82.4	81.6	82.4	82.8	83.8	84.6	82.6	80.5	82.3	84.3	82.5
6000	82.5	81.3	82.5	82.5	77.1	73.4	82.0	81.7	74.4	79.5	83.0	78.1	84.8
8000	76.4	81.7	79.1	81.7	83.6	83.1	83.1	84.7	79.9	83.7	76.2	81.5	74.2

Table IV

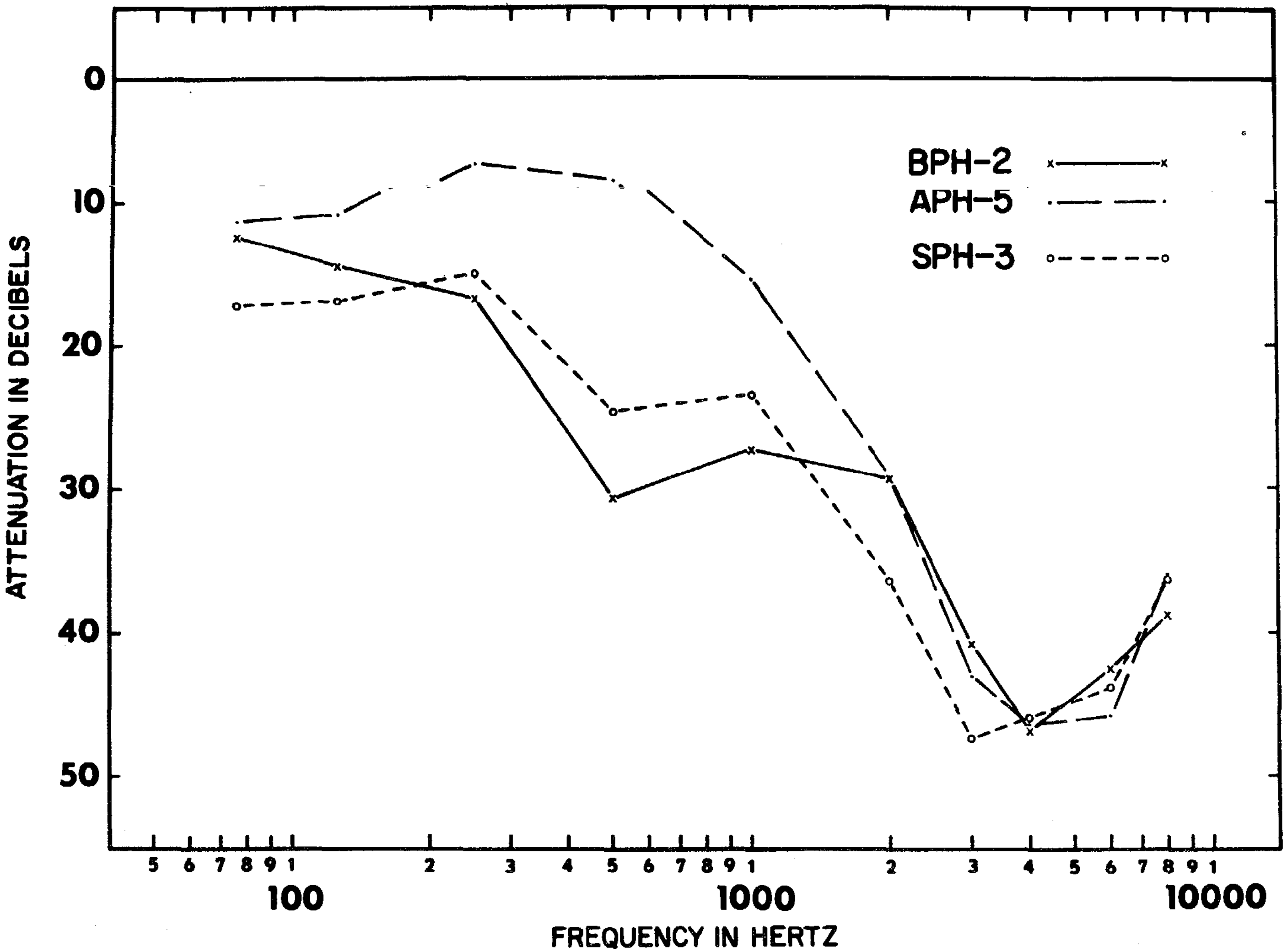
Mean Sound Pressure Level and Standard Deviation Values in Decibels (re 0.0002 Dyne/cm^2) of Ambient Acoustic Noise in the Industrial Acoustics Company 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. Also Shown are System Noise Data of the Instrumentation Used in Measuring the Acoustic Noise.

1/3rd Octave-Band Center Frequencies in Hertz	System Noise		Room Noise	
	Mean SPL Equiv.	Standard Deviation	Mean SPL	Standard Deviation
25	18.13	3.15	29.36	2.97
31.5	16.13	2.80	28.68	3.07
40	16.00	2.90	29.48	2.95
50	14.76	2.42	30.36	2.55
63	15.83	2.12	31.97	1.52
80	12.87	2.17	14.36	1.95
100	11.38	1.70	16.81	0.37
125	9.70	1.75	28.93	0.85
160	9.32	1.50	9.88	1.25
200	8.02	1.42	10.99	1.22
250	6.14	1.25	17.81	1.22
310	5.58	1.32	11.56	0.67
400	4.86	1.17	14.21	0.32
500	4.18	0.82	4.58	0.95
630	2.65	1.22	4.46	0.80
800	2.08	0.90	4.55	0.90
1,000	1.59	0.60	2.40	1.12
1,250	2.68	1.20	4.17	0.65
1,600	1.26	1.00	3.22	1.22
2,000	0.96	1.22	2.18	0.95
2,500	0.31	1.27	1.78	0.27
3,150	0.73	1.22	8.97	0.80
4,000	0.58	1.25	4.16	0.47
5,000	1.46	0.80	2.53	1.15
6,300	1.75	0	2.98	1.15
8,000	2.35	1.07	1.90	0.60
10,000	1.75	0	4.30	1.72
12,500	2.49	1.15	4.25	0
16,000	4.25	0	4.26	0.15
20,000	4.25	0	4.62	0.87
A	36.75	0	36.75	0
B	34.25	0	35.65	1.25
C	46.75	0	49.32	0.70
Lin	56.75	0	56.75	0

Table V

Mean Real-Ear Sound Attenuation and Standard Deviation Values Obtained with the BPH-2, Army APH-5, and the SPH-3 (Modified) Helmets.

	BPH-2		APH-5		SPH-3	
Test Frequencies in Hertz	Mean Attenuation Values in Decibels	Standard Deviation in Decibels	Mean Attenuation Values in Decibels	Standard Deviation in Decibels	Mean Attenuation Values in Decibels	Standard Deviation in Decibels
75	12.46	4.29	11.34	5.03	17.20	3.50
125	14.42	3.17	10.86	4.55	16.91	3.70
250	16.66	1.59	5.98	4.15	14.95	3.36
500	30.58	2.88	7.11	3.52	24.66	3.07
1000	27.25	4.25	15.37	4.84	23.38	4.89
2000	29.17	4.33	29.11	5.61	36.40	5.11
3000	40.84	3.04	43.00	5.26	47.32	5.86
4000	46.90	3.37	46.26	7.07	45.94	5.77
6000	42.49	9.75	45.83	6.92	43.79	5.29
8000	38.77	6.86	35.97	10.83	36.24	7.82



MEAN REAL-EAR SOUND ATTENUATION OF THE BPH-2,
ARMY APH-5, AND THE SPH-3 (MODIFIED) HELMETS.

Figure 4

The small differences between BPH-2 and the Army APH-5 data at 75 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz were not statistically significant. But the superiority of the BPH-2 is reflected in the large differences at test frequencies 205 Hz, 500 Hz, and 1000 Hz, which were 10.68 db, 23.47 db, and 11.88 db, respectively. The 3.56 db greater attenuation of the BPH-2 at 125 Hz was also statistically significant at the one per cent level of confidence.

Figure 5 contains graphic displays of decile ranks of the attenuation values for three helmets. These data serve to show the relative efficiency of ear protective devices by decile ranks the values of which were derived in USAARU REPORT 66-6. Table VI contains the decile rank values from that report.

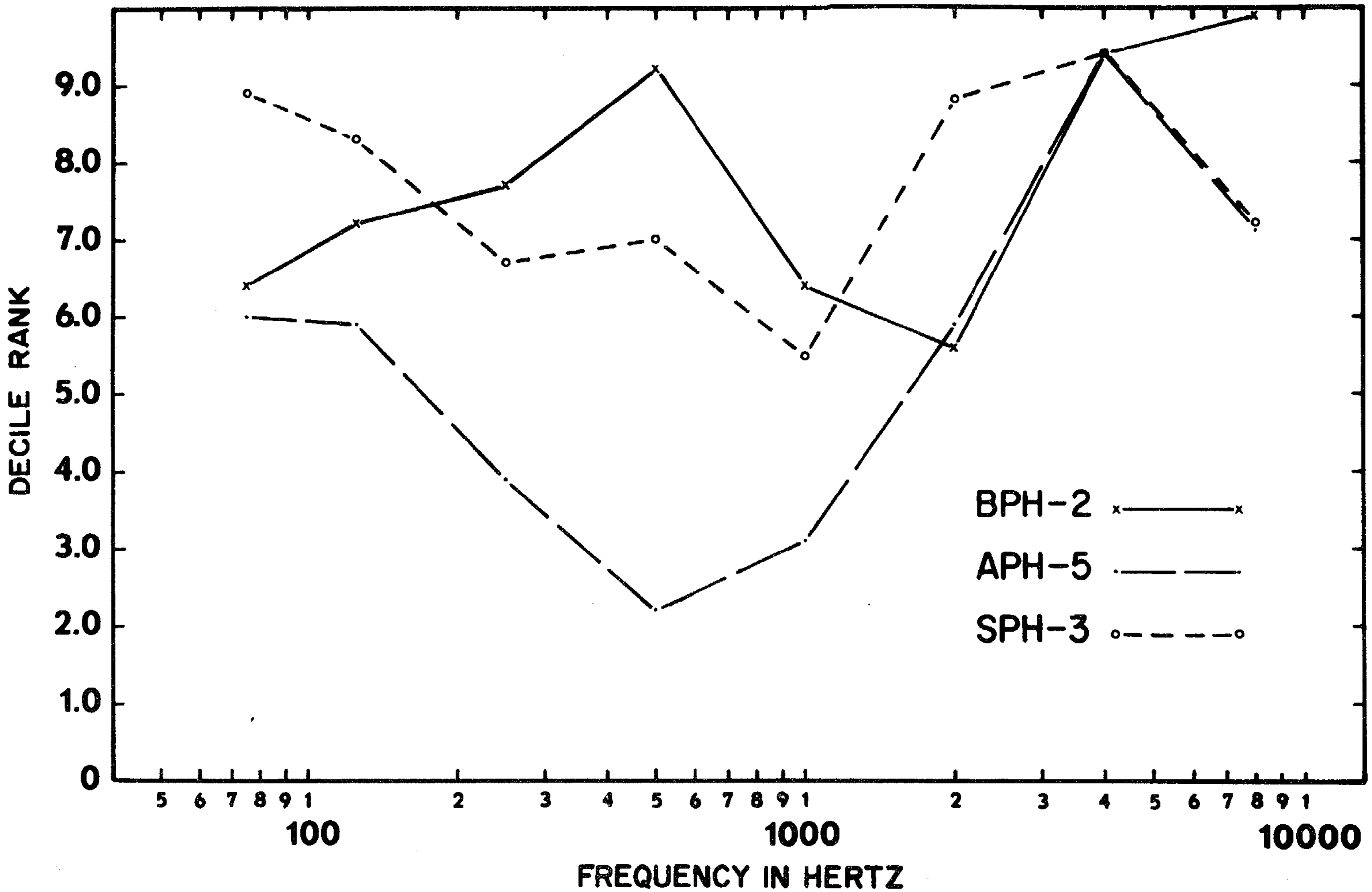
An overall evaluation of the BPH-2 is perhaps best derived from the decile rank graph. Its superior attenuation characteristics from 125 Hz through 1000 Hz are obvious. This portion of the spectrum is vital to voice communications. It would be very desirable to have these characteristics in a standard Army helmet for the achievement of less masking by external noise and thereby aiding in the reduction of overall speech sound pressure level. Presently, earphone output levels are above the maxima recommended by various damage risk criteria.

CONCLUSIONS AND RECOMMENDATIONS

Real-ear sound attenuation characteristics of the Navy BPH-2 helmet were determined by standard procedures and equipment recommended by ASA Z24.22-1957. Ten subjects were tested three times each. This is the minimum amount required by the ASA specifications. Comparisons of the results of these tests were made with the results obtained from USAARU Report 67-6 and USAARU Report 67-8 on the attenuation characteristics of the standard Army APH-5 and the Navy SPH-3 (Modified), and these comparisons show that:

(1) The SPH-3 (Modified) has superior acoustic attenuation characteristics at 75 Hz, 125 Hz, 2000 Hz, and 3000 Hz.

(2) The BPH-2 has sound attenuation significantly greater than the Standard Army APH-5 at 125 Hz, 250 Hz, 500 Hz, and 1000 Hz which is a vital portion of the Speech communication spectrum.



DECILE RANKS OF REAL-EAR ATTENUATION VALUES
OBTAINED WITH THE APH-5, SPH-3 (M), AND BPH-2 HELMETS

Figure 5

Table VI

Decile Values in Decibels for Mean Real-Ear Attenuation Data of 36 Ear Protective Devices.

Deciles	75 Hz*	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
D_1	2.3	0.3	0.0	3.8	2.4	15.8	27.8	24.8
D_2	4.1	2.9	3.1	7.1	11.7	19.1	29.6	26.6
D_3	5.9	4.4	4.4	10.3	15.4	21.3	31.3	28.4
D_4	7.3	6.9	6.2	13.7	18.9	25.6	32.9	30.2
D_5	9.5	9.0	9.5	16.5	22.0	26.5	34.7	32.5
D_6	10.9	11.1	13.7	18.8	25.8	29.3	35.8	34.0
D_7	13.9	14.1	15.6	24.7	30.2	32.7	37.6	35.9
D_8	15.2	15.4	18.3	29.3	32.3	34.8	38.4	37.4
D_9	17.1	18.7	20.9	30.3	35.6	36.7	41.9	38.3

* Computed from data of 34 ear protective devices.

(3) The characteristics of the BPH-2 and the APH-5 are similar from 2000 Hz through 8000 Hz.

A previously reported test of the Navy SPH-3 (Modified) helmet has shown that this immediately available helmet has acoustical characteristics superior to the presently standard Army APH-5. The findings in this report also show that the BPH-2 helmet is an efficient attenuator of sound in the vital speech spectrum. In view of the need for ear protection and improved speech communications, it is recommended that the BPH-2 and the SPH-3 (Modified) be considered for use by Army aviation personnel.

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